SIRD STOCHASTIC MARKOV MODELLING OF COVID-19 PANDEMIC IN SOME SELECTED WEST AFRICAN COUNTRIES

BY

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The global COVID-19 pandemic has significantly impacted economies worldwide, including those of West African countries. COVID-19 belongs to the Coronavirus family, primarily affecting the human respiratory system. This research focuses on assessing COVID-19 transmission rates in selected West African nations through Stochastic Markov analysis, utilizing Susceptible, Infective, Recovered, and Death (SIRD) states. By applying the stochastic Markov model to WHO COVID-19 data, the study reveals transition probabilities for SIRD states in Liberia (61% susceptible to infective), The Gambia (53% susceptible to infective), and Nigeria (45% susceptible to infective). The research highlights a higher recovery rate in The Gambia (53%) and a lower one in Liberia (37%). Moreover, Nigeria tops the list for transition from infective to death (absorbing) state with 44%, while The Gambia follows with 7%. The study emphasizes the importance of strict adherence to COVID-19 guidelines to ensure safety.

Keywords: COVID-19, WHO, SIRD, Pandemic, Nigeria, Liberia, The Gambia, West Africa.

Introduction

Amidst the challenges of COVID-19, we come to realize the true value of our health, a priceless treasure from God Almighty to man. Thus, we can overcome this storm, and emerge stronger and more resilient as a community if we take precautionary steps. It is of utmost importance to note that coronavirus is a major pathogen that primarily targets the human respiratory system and gradually leads to death if not handled properly. There are previous outbreaks of Coronaviruses (CoVs) before now, the previous outbreaks include the Middle East Respiratory Syndrome (MERS)-CoV and the Severe Acute Respiratory Syndrome (SARS)-CoV, both of which have been recently recognized as significant health threats to the public. In late December 2019, a group of patients with pneumonia of unknown origin were admitted to different hospitals and linked epidemiologically to the seafood and wet animal market in Wuhan, China (Bogoch et al., 2020; Lu, Stratton, and Tang, 2020). The World Health Organization (WHO) named it COVID-19 on February 11, 2020. Early reports indicated that potential COVID-19 outbreaks would have a basic reproductive number greater than 1, ranging from 2.24 to 3.58 (Zhao et al., 2020). COVID-19 is a pandemic that has caused widespread fear, uncertainty, and loss of life globally, affecting not only public health but also the global economy. By February 20, 2020, 2130 deaths had been confirmed across 5 continents and 26 countries. Common symptoms of COVID-19 include fever, dry cough, and dyspnea, which are similar to those seen in SARS and MERS outbreaks in 2003 and 2012, respectively. However, symptoms like nausea, abdominal discomfort, and vomiting differ among the study population (Wang et al., 2020). SARS, MERS, and COVID-19 are all part of the coronavirus family, with SARS-CoV causing SARS, MERS-CoV causing MERS, and SARS-CoV-2 causing COVID-19. SARS-CoV-2 is closely related to SARS-CoV, but COVID-19 stands out for its higher infectivity and contagion compared to SARS and MERS. COVID-19 patients also experience intestinal symptoms like diarrhea, while MERS and SARS patients have lower occurrences of such symptoms.

The incubation period for COVID-19 contagion is approximately 5.2 days (Li et al., 2020). The time from the onset of COVID-19 symptoms to patient mortality varied between 6 to 41 days, with a median of 14 days (Wang, Tang, and Wei, 2020). This period is influenced by the patient's age and the state of their immune system. Patients over 70 years old generally have weaker immune systems than those below 70 years old (Wang, Tang, and Wei, 2020).

Common symptoms of COVID-19 include fever, dry cough, and fatigue. Additional symptoms may include phlegm or sputum, hemoptysis, headache, dyspnea, diarrhea, and lymphopenia (Carlos et al., 2020; Huang et al., 2020; Ren et al., 2020; Wang, Tang, and Wei, 2020). However, COVID-19 exhibits unique clinical characteristics that differentiate it from other coronaviruses. It primarily targets the lower airway, marked by symptoms like sneezing, sore throat, rhinorrhea, and the recent addition of loss of taste and smell (Lee et al., 2003; Assiri et al., 2013; NCIRD, 2020). Originating from Wuhan, China, COVID-19 has spread globally with a significant increase in cases and fatalities. The main mode of transmission is from person to person, though the large number of infected individuals at the Wuhan wet market suggests possible zoonotic origins. Transmission occurs through direct contact with infected individuals or by coming into contact with respiratory droplets from coughs and sneezes. The virus can survive on surfaces for up to 48 hours, emphasizing the importance of frequent handwashing and maintaining social distancing of at least 2 meters. Hugging, kissing, and handshaking are discouraged to prevent further spread.

Outside China, the first reported COVID-19 case was in Thailand on January 13, 2020 (Amira et al., 2020). The virus has since spread to 180 countries with over 930,000 infections and more than 47,000 deaths reported globally as of April 1, 2020. Countries like the United States of America, Italy, Spain, and India have been significantly affected by the COVID-19 pandemic.

Methodology

The WHO COVID-19 data ranging from the inception dates of the three selected West African countries: Liberia, The Gambia, and Nigeria to December 2020 was used.

The Markov Chain Model

The daily observed COVID-19 data will follow 4 states, S_t; where $S_t = 0$, if the state, which would otherwise be referred to as the 'SUSCEPTIBLE' state of the COVID-19 daily data.

$S_t = 1$; if the state, which would henceforth be referred to as the 'INFECTIVE' state of the COVID-19 daily data

$S_t = 2$; if the state, which would henceforth be referred to as the 'RECOVERED' state of the COVID-19 daily data.

$S_t = 3$; if the state, which would henceforth be referred to as the 'DEATH' state of the COVID-19 daily data.

Thus, whether states $S_t = 0,1,2,3$; the process respectively would be regime 0, 1, 2, 3; so that there would be an observed change between the period t and t + 1. Thus, the observed change Y_t is a random draw that follows a normal distribution. That is;

$Y_t \sim N(\mu_0, \sigma_0^2)$ distribution for the 'SUSCEPTIBLE' state (i)

$Y_t \sim N(\mu_1, \sigma_1^2)$ distribution for the 'INFECTIVE' state (ii)

$Y_t \sim N(\mu_2, \sigma_2^2)$ distribution for the 'RECOVERED' state (iii)

$Y_t \sim N(\mu_3, \sigma_3^3)$ distribution for the 'DEATH' state (iv)

Therefore the probabilities of the switching strategies amongst the four different states and regimes are defined by the P_{ij} which is the transition probability. Hence the transition probability state can be switched amongst the states or that a particular state (i) be followed by another state (j). The current COVID-19 transmission rate depends on the preceding COVID-19 transmission rate and not the past.

The Markov Chain (MC) is given as;

$MC = P(X_{t+1} = x/X_1 = x_1, X_2 = x_2, \ldots, X_t = x_t)$ (iv)

Thus;

$MC = P(X_{t+1} = x_{t+1}/ X_t = x_t)$ (v)

Where $t \in N$

X is the COVID-19 transmission rate at different periods. Therefore, the P_{ij} is given as;

$(P_{ij}) = P_{(ji)}$ where i and j $\in S$. The matrix of the transition probability P_{ij} becomes;

$$P_{ij} = \begin{bmatrix} P_{00} & P_{01} & P_{02} & P_{03} \\ P_{10} & P_{11} & P_{12} & P_{13} \\ P_{20} & P_{21} & P_{22} & P_{23} \\ P_{30} & P_{31} & P_{32} & P_{33} \end{bmatrix}$$

Where i, j ∈ S and

$P_{00} = P(\varphi_k = 0 / \varphi_{k-1} = 0) = \alpha$ (vi)

$P_{01} = P(\varphi_k = 1 / \varphi_{k-1} = 0) = \beta$ (vii)

$P_{02} = P(\varphi_k = 2/\varphi_{k-1} = 0) = 1 - \alpha - \beta$ etc (viii)

Such that $0 \le \alpha, \beta, \gamma, \delta, \varepsilon, \zeta \le 1$ and their sum, that is row-wise cannot exceed 1.

$P_{00} + P_{01} + P_{02} + P_{03} = 1$ (ix)

Therefore the four states observed frequency F_{ij} table would be given as;

Table I 4 States Observed Frequency Table

	Current COVID-19 day				
	S	I	R	D	TOTAL
Previous COVID-19 day S	F_{SS}	F_{SI}	F_{SR}	F_{SD}	$F_{S.}$
I	F_{IS}	F_{II}	F_{IR}	F_{ID}	$F_{I.}$
R	F_{RS}	F_{RI}	F_{RR}	F_{RD}	$F_{R.}$
D	F_{DS}	F_{DI}	F_{DR}	F_{DD}	$F_{D.}$

Where F_{ij} is the observed frequency from the COVID-19 transmission data

F_{SS} = number of COVID-19 Susceptible states coming from or switched from another Susceptible state.

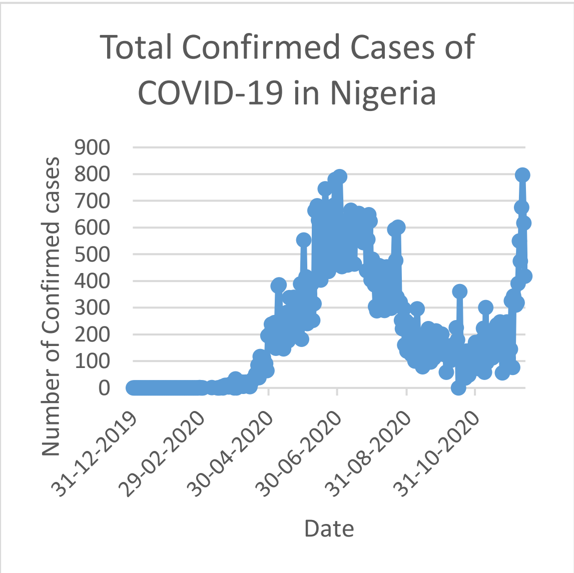
F_{SI} = number of COVID-19 Susceptible states coming from or switched from COVID-19 Infective state and so on.

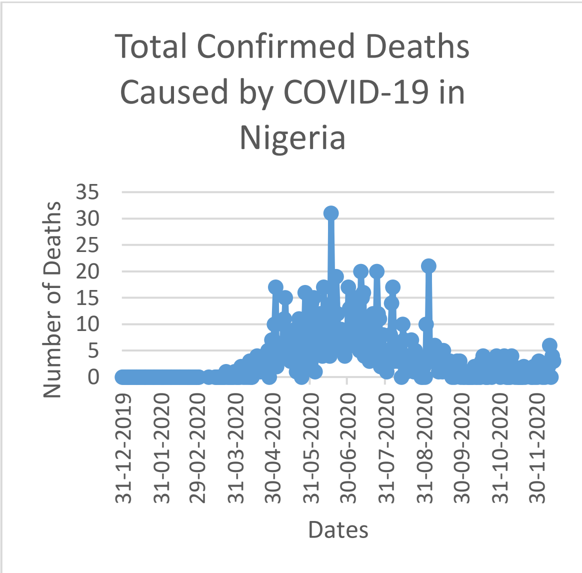
$F_{S.} = F_{SS} + F_{SI} + F_{SR} + F_{SD}$, which is the total frequency or number of the COVID-19 Susceptible state and so on

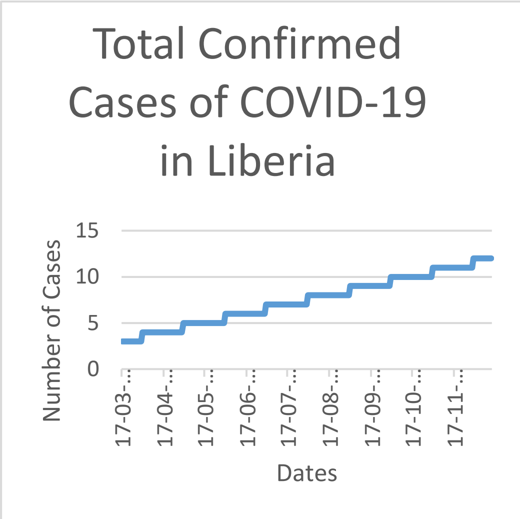
The maximum likelihood estimators of P_{ij}, where i, j = s, i, r, d states; where s,i,r,d represent Susceptible, Infective, Recovered, and Death respectively.

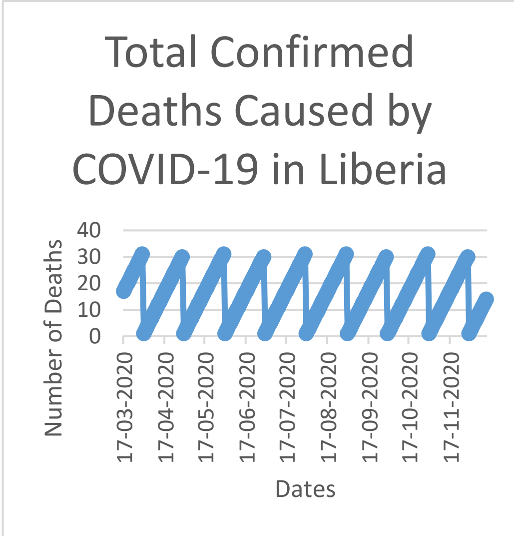
Analysis

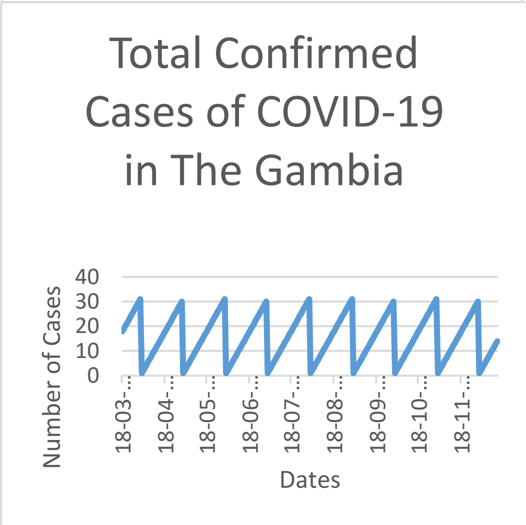
Below are the COVID-19 confirmed death cases for Liberia, The Gambia, and Nigeria respectively.

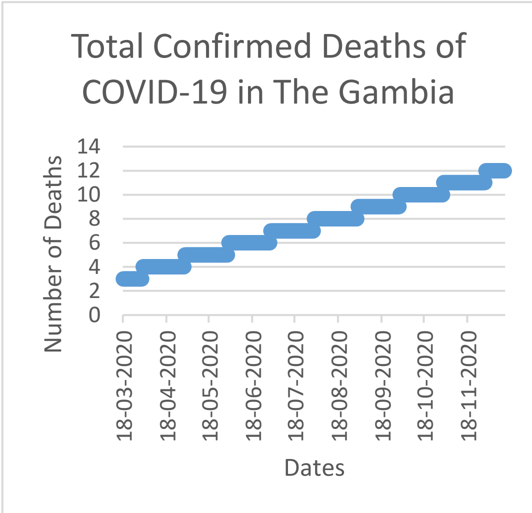












The graphs above show the total confirmed cases and deaths for the 3 West African countries under study. From the graphs above, the total confirmed cases of covid-19 trend in Nigeria, the Gambia, and Liberia are fluctuating. The series 'cases' point at 12th of December, 2020 had values of 796, 12, and 12 respectively for Nigeria, the Gambia, and Liberia. The death values for Nigeria, the Gambia, and Liberia are 0, 12, and 12 respectively.

The table below shows the state frequencies and the transition probability values corresponding to the state switching.

Table I: STATE FREQUENCIES, AND CORRESPONDING TRANSITION PROBABILITY MATRICES FOR LIBERIA, THE GAMBIA, AND NIGERIA (FROM Inception Dates to December 14th, 2020)

Countries	Frequencies	Transition probability matrices	Switching states
Liberia	$\begin{bmatrix} 22 & 35 & 0 & 0 \\ 0 & 20 & 23 & 19 \\ 19 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 0.39 & 0.61 & 0 & 0 \\ 0 & 0.32 & 0.37 & 0.31 \\ 0.95 & 0 & 0.05 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} SS & SI & SR & SD \\ IS & II & IR & ID \\ RS & RI & RR & RD \\ DS & DI & DR & DD \end{bmatrix}$

The Gambia	$\begin{bmatrix} 8 & 9 & 0 & 0 \\ 0 & 6 & 8 & 1 \\ 7 & 0 & 5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 0.47 & 0.53 & 0 & 0 \\ 0 & 0.4 & 0.53 & 0.07 \\ 0.58 & 0 & 0.42 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} SS & SI & SR & SD \\ IS & II & IR & ID \\ RS & RI & RR & RD \\ DS & DI & DR & DD \end{bmatrix}$
Nigeria	$\begin{bmatrix} 65 & 54 & 0 & 0 \\ 0 & 13 & 50 & 49 \\ 71 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 0.55 & 0.45 & 0 & 0 \\ 0 & 0.12 & 0.45 & 0.44 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} SS & SI & SR & SD \\ IS & II & IR & ID \\ RS & RI & RR & RD \\ DS & DI & DR & DD \end{bmatrix}$

From the table above, S means susceptible individuals who can contract the disease, at this point, they are not infected yet. SS, SI, SR, and SD means switching from a susceptible state to another susceptible state, or infective state, or recovered state, or death state.

I mean infective, these are individuals that have the disease and can also infect others, and thus, they are the carriers. IS, II, IR, and `ID means switching from a state of infective to another state of infective, or susceptible, etc.

R means recovered individuals. These are individuals that are formerly infected and no longer considered infected.

D means death, these are individuals that died, they didn't recover or they recovered but later died due to the COVID-19 disease. The 'D' state is absorbing.

Following the transition probability matrices, it was discovered that the transition probabilities of the SIRD state's series were 0.61 (61%) for Liberia, that is, from a susceptible state to an infective state, 0.53 (53%) for The Gambia, and 0.45 (45%) for Nigeria respectively. The findings of the study show that the recovery rate was higher with The Gambia (53%) and lower with Liberia (37%). The infective state to death (absorbing) state had Nigeria top the list with 44%, and The Gambia with 7% respectively. Nigeria had the highest frequency of 54 switchings from a susceptible state to an infective state followed by Liberia with 35 and the Gambia, with 9 respectively. It simply implies that Nigerians really didn't observe the COVID-19 safety rules and thus the high rate as regards the figures.

Table 2: TRANSITION PROBABILITY TABLE OF REMAINING IN A PARTICULAR STATE

Probability switching states		LIBERIA	The GAMBIA	NIGERIA
P_{SS}	P_{00}	0.39	0.47	0.55
P_{II}	P_{11}	0.32	0.4	0.12
P_{RR}	P_{22}	0.05	0.42	0
P_{DD}	P_{33}	1	1	1

From the table above, 55% of the Nigerian population are prone to be infected with the deadly COVID-19 disease while 47% for the Gambia and finally, Liberia with 39%. The absorbing state of death (an absorbing state is a state that once one enters, he or she remains there. It is a state of no return) has one all through for the countries under study, which implies that the state cannot be left once entered.

Conclusion

The SIRD Stochastic Markov model revealed that out of the three West African countries under study, Nigeria is more susceptible to been infected with the deadly covid-19 disease. Liberia and the Gambia have the highest infected person with Nigeria been least on the row. The findings of the study show that the recovery rate was higher with The Gambia (53%) and lower with Liberia (37%). The infective state to death (absorbing) state had Nigeria top the list with 44%, and The Gambia with 7% respectively. From the results, we were able to identify the probability and percentages of the countries that were prone to be infected and those that were more susceptible than the others. The findings from our work should assist the governments of the three West African countries in managing the COVID-19 disease properly by not totally relaxing the lockdown. Hospitals, markets, churches, banks, streets amongst others should be fumigated regularly. Surveillance should be more on the defaulters of the COVID-19 rules and due punishment should be melted out on them.